

Vehicle Staging Analysis of the Transition to Supersonic Retropropulsion During Mars Entry, Descent, and Landing

Completed Technology Project (2014 - 2018)



Project Introduction

The landing of the Mars Science Laboratory represents the upper limit of current Entry, Descent, and Landing (EDL) capabilities for Mars exploration. The succession from the current state of the art along NASA's goal of extending and sustaining human presence in our solar system will require landing large robotic (~10 mT) and human class payloads (~40-80 mT) on Mars with landed accuracies on the order of meters. To rise to this challenge, new EDL technologies must be developed. The Entry, Descent, and Landing Systems Analysis (EDL-SA) Study identifies supersonic retropropulsion (SRP) as a promising, mission enabling technology for high mass and human Mars missions. The goal of my research is to develop nominal, detailed designs and requirements for SRP transition architectures for Mars high mass entry vehicles. These configurations are envisioned to guide future SRP technology development and investigation, specifically in the definition of propulsion system requirements, aeroscience configuration-dependent investigations, and further SRP configuration and transition architecture development. My research into this topic will include an extensive literature review of recent configuration, packaging, and staging analyses applicable to high mass Mars missions as well as review of relevant sub-systems literature such as hypersonic decelerators, SRP sub-systems, terminal descent propulsion and control requirements, previous transition architectures, and transition separation methods. Building off the transition architectures recommend by the EDL-SA study, I will develop six degree-of-freedom models and simulations of aerodynamic and multibody dynamic behavior of high mass entry vehicles relative to their jettisoned masses over nominal Mars EDL trajectories. To aid the multibody dynamics analysis, CFD solvers will be used to determine detailed aerodynamic interactions between entry bodies and jettisoned masses. Specific aerodynamic interactions to be investigated, characterized, and modeled include the suction phenomena occurring between an entry body and an ejected mass shortly after jettison and near and far-field recontact risks. In parallel with aerodynamic and multibody dynamic analyses, ballistic coefficient ratios between entry vehicles and jettisoned masses will be characterized and developed such that recontact risks are minimized. Supersonic ballistic analyses will build off of similar subsonic analyses for previous Mars missions. Detailed design analysis will focus on characterizing and designing separation systems to disconnect and jettison hypersonic decelerators away from the entry body during supersonic flight. Heritage pyro-separation and guide-rail systems will be evaluated for potential feed-forward inclusion into supersonic separation systems. Based on the recommendations of the EDL-SA study, entry vehicle divert maneuvers following jettison events and RCS thrusting maneuvers to dispose of aeroshells after separation will be considered and analyzed as possible methods to minimize jettisoned mass recontact risks. Multi-objective optimization techniques will be used to trade potential recontact risks with transition system complexity, reliability, and cost. To determine contributions to total mission uncertainty due to these transition systems, I will perform Figure of Merit evaluations according to the



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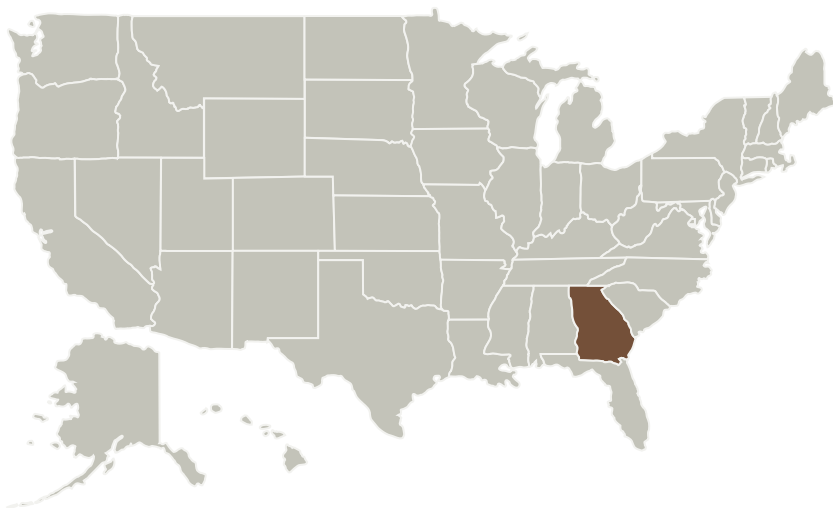


techniques and weighting schemes defined in the EDL-SA study. As a final component of my research, I will investigate alternatives to configurations considered in the EDL-SA that do not necessarily require a supersonic forebody jettison event. Specifically, aftbody SRP configurations will be investigated. My analysis will focus on defining derived requirements on transitions architectures and systems for these configurations. All previous transition analyses will be reapplied to aftbody SRP configurations so that meaningful comparisons can be drawn between different configuration types.

Anticipated Benefits

Extending and sustaining human presence in our solar system will require landing large robotic (~10 mT) and human class payloads (~40-80 mT) on Mars with landed accuracies on the order of meters. To rise to this challenge, new EDL technologies must be developed. The Entry, Descent, and Landing Systems Analysis (EDL □ SA) Study identifies supersonic retropropulsion (SRP) as a promising, mission enabling technology for high mass and human Mars missions. The goal of this project is to develop nominal, detailed designs and requirements for SRP transition architectures for Mars high mass entry vehicles. These configurations are envisioned to guide future SRP technology development and investigation, specifically in the definition of propulsion system requirements, aeroscience configuration-dependent investigations, and further SRP configuration and transition architecture development.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Georgia Institute of Technology-
Main Campus (GA Tech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Robert D Braun

Co-Investigator:

David J Blette

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Organizations Performing Work	Role	Type	Location
Georgia Institute of Technology-Main Campus(GA Tech)	Lead Organization	Academia	Atlanta, Georgia

Primary U.S. Work Locations

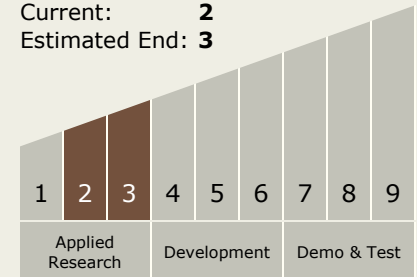
Georgia

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
 - TX09.2 Descent
 - TX09.2.2 Supersonic Retropropulsion

Target Destination

Mars